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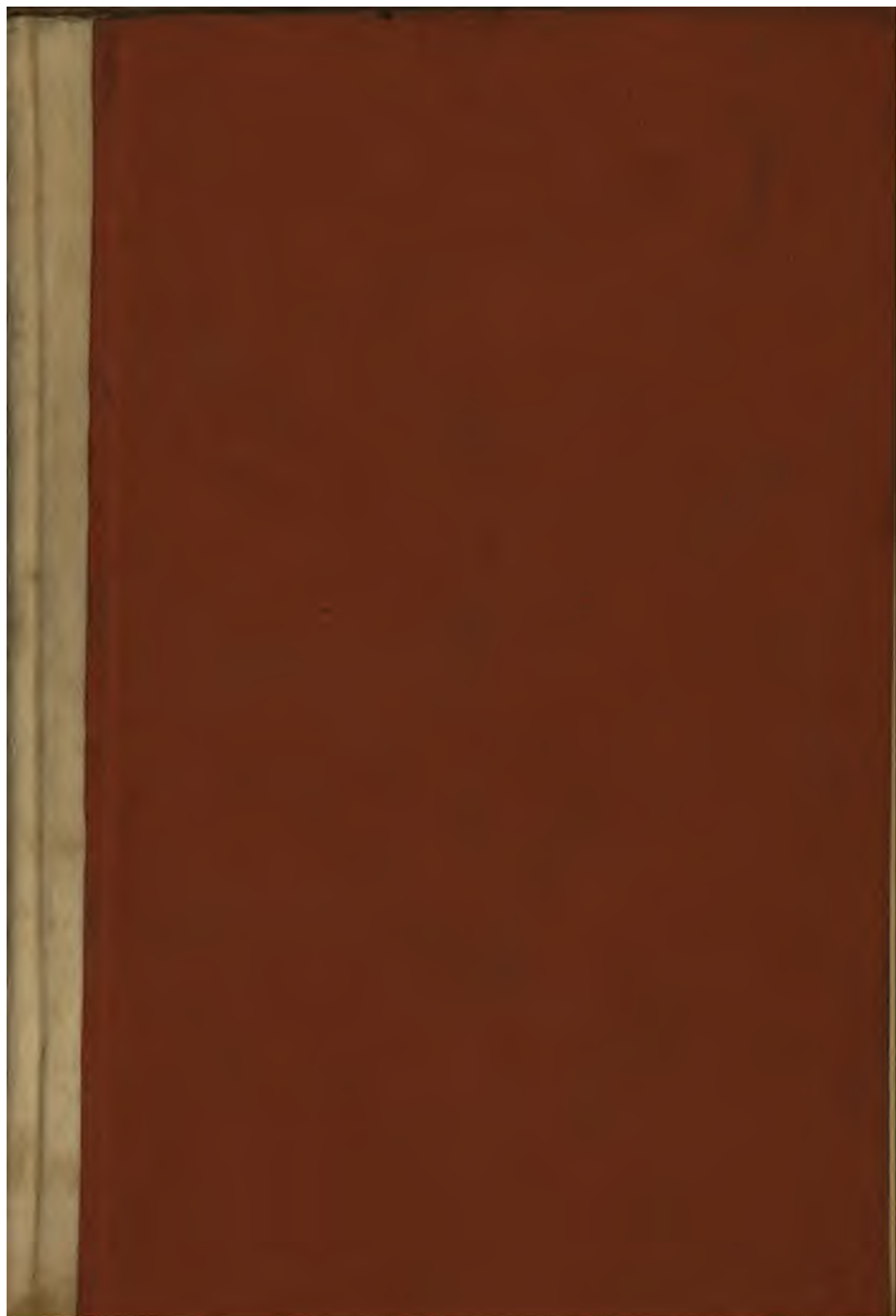
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HAND-BOOK
TO
JOHNSTON'S ILLUSTRATIONS
OF THE
ELECTRO-DEPOSITION OF
METALS

BY
ALEXANDER WATT
AUTHOR OF "ELECTRO-METALLURGY," ETC. ETC.

ILLUSTRATED BY COLOURED DIAGRAMS

W. & A. K. JOHNSTON
EDINBURGH AND LONDON
1881



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INTRODUCTION.

I.

Discovery of Voltaic Electricity—How it is produced —Various Forms of Voltaic Battery—Dynamo- Electricity—Thermo-Electricity.

BEFORE entering into the practical applications of the invisible power known as Galvanism, or Voltaic Electricity, it will be well to consider how it was that an electric discharge accidentally manifested itself in the simple yet positive way which ultimately led to the grand discovery of the Voltaic Battery.

In the year 1790 the wife of Professor Galvani of Bologna being in a declining state of health, employed as a restorative a soup made with frogs—a common remedy in those days both in France and Italy. A number of these animals, ready skinned for cooking, were lying on the Professor's laboratory-table, near an electrical machine. While the machine was in action an attendant happened to touch with the point of a scalpel the crural nerve of one of the frogs that was not far from the prime conductor of the machine, when the limbs were instantly thrown into strong convulsions. This remarkable phenomenon was observed during Galvani's absence, but on his return his wife made known to him the strange fact, and the Professor soon set to work to investigate the matter. He observed that the limbs of the frog were only convulsed when a spark was drawn from the prime conductor of the electrical machine, while the nerve was at the same time touched with some substance which was a conductor of electricity.

The important phenomenon was subsequently investigated by Volta, who in a letter to Sir Joseph Banks, the then President of the Royal Society, announced his invention of the apparatus known as the Voltaic Pile (fig. 10), which consisted of pairs of zinc and copper plates, with a layer of paper or flannel moistened with salt-and-water between each pair. A great number of pairs of plates, with the intervening layer of moistened paper, were piled above one another, somewhat after the fashion shown at fig. 10, and thus a very powerful battery was formed. To this invention we are indebted for the many forms of so-called, but misnamed, galvanic batteries which have done, and are still doing, so much service both to science and art, thus aptly illustrating the line that

“Great events from little causes spring.”

We will now endeavour to explain the principles upon which electrical action is set up, and the conditions necessary for its development.

If we take a strip of zinc and immerse it in a weak solution of sulphuric acid, as in fig. 1, we observe that bubbles of gas appear upon the surface of the metal. Now water, as is well known, is composed of two gases, *hydrogen* and *oxygen*. When the zinc is attacked by the acidulated water, hydrogen is liberated and escapes into the air, while the oxygen with which it was combined acts upon the surface of the zinc, forming oxide of zinc, and this is at once taken up by the sulphuric acid, forming sulphate of oxide of zinc, a substance soluble in water.

If we next place a strip of copper and a strip of zinc in the acid solution and allow them to come in contact, as in fig. 2, we find that the hydrogen no longer rises from the zinc, but that it is liberated on the surface of the copper. At the instant when the metals come in contact electricity is generated, and the current, proceeding from the zinc, passes, in the direction of the arrow to the copper, again returning to the zinc in unbroken

circuit. If we now separate the strips of metal, the hydrogen will again appear on the surface of the zinc; and owing to the circuit, as it is termed, being thus broken, electrical effects cease to be developed.

In fig. 3 we have an arrangement consisting of a pair of plates, one of zinc (Z) and another of copper (C), each plate having a copper wire attached. This arrangement is in reality a single fluid battery. Now if we place the ends of the two wires in a solution of sulphate of copper (bluestone of the shops), we shall find that the end of the wire proceeding from the zinc will in a few moments become coated with a bright red deposit of pure copper. To illustrate this interesting phenomenon with greater effect a small piece of sheet copper may be attached to the wire connected to the copper strip, and a smaller piece of the same metal attached to the wire proceeding from the zinc. In a little while the smaller piece of copper will have become coated with pure copper, while the larger piece will have become reduced in weight. In time the whole of the copper will become dissolved at A and an equivalent amount of the metal will be deposited at B. The rationale of the process may be thus described: The electric current decomposes the copper solution, the hydrogen of the water instead of escaping into the air takes the place of the copper in the solution, while the oxygen attacks the copper A, forming oxide of copper; the sulphuric acid which is set free dissolves this oxide, again forming sulphate of oxide of copper, whereby the solution is kept up to its normal condition. Thus it will be seen that so long as electrical action is going on the dissolution of the copper at A and the deposit of copper at B must continue until the whole of the copper A is dissolved. This process is termed *electrolysis*, and the solution is termed the *electrolyte*.

In each case the arrows indicate the course traversed by the electric fluid.

Fig. 4 represents a series of zinc and copper plates arranged

alternately, but connected in pairs by means of copper wire. One end of this series terminates in a zinc plate and the other in a plate of copper. The zinc is called the *positive* element and the copper the *negative* element. The end of the wire N issuing from the zinc is termed the *negative pole*, whilst that from the copper P is the *positive pole*. We find, therefore, that a voltaic battery consists essentially of two metals of opposite character excited by chemical action. The metal dissolved is the positive element and the undissolved metal the negative element.

Having thus far given a brief outline of the principles upon which voltaic electricity is generated, we may now turn our attention to the more complete forms of apparatus which have from time to time been designed by their respective inventors, but all based upon the great discovery of Volta—the production of an electric current by chemical action upon metals of opposite character.

Volta's discovery naturally led other scientific men of the day to investigate the matter still farther, and it soon became apparent that, however interesting and important as a means of illustrating a grand principle, the pile of Volta was susceptible of considerable improvement. It was found that the weight of the upper upon the lower parts of the voltaic pile pressed the liquid out of the saturated layers of cloth, and thus greatly diminished the usefulness of the apparatus. To overcome this defect, Cruickshanks placed the metallic elements in a wooden trough, and fixed the plates into grooves by means of resinous cement. Volta, however, greatly improved upon this in the construction of his *couronne des tasses*, as represented in fig. 4.

Dr. Wilkinson modified and improved this arrangement again by uniting the plates in pairs, and fastening them to a wooden beam or bar of wood. These plates, when the battery was required for use, were lowered into a wooden trough divided into compartments each of which was filled with an acid solution.

Dr. Wollaston subsequently discovered that greater electrical

effects were obtained when *both sides* of the zinc plates were faced by a surface of copper. The diagram fig. 8 represents the arrangement designed by that eminent chemist.

The constant battery of Professor Daniell (fig. 11) became exceedingly popular soon after its first introduction, owing to the little trouble involved in its use, the constancy of its action, and the simplicity of its construction. This battery consists of a cylindrical copper vessel, a porous cell, an amalgamated zinc bar, with binding screw attached. The porous cell is nearly filled with dilute sulphuric acid, and a strong solution of sulphate of copper is placed in the outer copper cylinder. For electro-typing purposes, and for gilding and silvering upon a small scale, this is a valuable addition to our numerous forms of voltaic battery. A compound Daniell's battery of twelve cells is shown at fig. 12. It will be observed that the elements in this group are arranged alternately, that is, the zinc of one cell is united to the copper of the next, and so on, terminating in a zinc bar at one end of the group and a copper cylinder at the other. To each of these elements a copper wire is attached by a binding screw. This is termed an *intensity* arrangement, and is generally adopted for producing powerful effects, such as the electric light, for instance. In electro-deposition, however, it is necessary to adopt what is known as the *quantity* arrangement, that is to say, the wires proceeding from the copper elements are united in one group, and the wires issuing from the zinc elements in another group. By this arrangement we obtain the full quantity of the current without multiplying its intensity, and are enabled to deposit a large quantity of metal without injuring the solution.

A very ingenious battery was invented by the late Alfred Smee, and, like the well-known Daniell's battery, it attained immense popularity. Indeed at the present time it is much in favour for experimental purposes. Smee's battery (fig. 7) consists of two plates of zinc amalgamated with mercury or quicksilver,

a thin sheet of platinized silver foil, secured to a wooden frame. The plates are inserted in a porcelain or glass vessel, which is nearly filled with a solution of sulphuric acid; one binding screw connects the two zinc plates and another binding screw is attached to the upper edge of the silver plate.

Another important battery is that known as the Bunsen battery; and since it is much employed in the arts of gilding, brassing, and nickel-plating, its construction will be interesting to the student. This battery (fig. 9) consists of an outer jar, which is commonly made of stoneware, a cylinder of amalgamated zinc, with binding screw attached to its upper rim; a porous cell, and a block or bar of graphite or carbon—a substance obtained from gas-retorts—a binding screw is fastened to the upper end of the carbon. The outer vessel is charged with a strong solution of sulphuric acid, and the porous cell is nearly filled with strong nitric acid. This is an exceedingly powerful battery, and when arranged in a series, as in fig. 12, is capable of producing a very powerful electric light from two carbon points, as shown in fig. 22. Sometimes double plates of carbon are employed, as in the American twin carbon battery (fig. 13). This arrangement yields a very powerful current, and is growing much in favour.

Walker's platinized carbon battery, which has been much employed for telegraph purposes, consists in using platinized carbon plates in place of the platinized silver foil employed in the Smee battery. Mr. Walker speaks highly of his battery for electrotyping purposes.

Having turned our attention to the principal forms of voltaic battery which are more or less applicable to the purposes of electro-deposition, a brief reference to other means of obtaining the electric current will form a necessary conclusion to this part of our discourse.

In the year 1831 Faraday discovered that by causing a copper plate to rotate between two poles of a magnet, a magneto-

electric current was obtained. He also found that the current was produced by sliding a coil of insulated wire upon a steel bar magnet. This great discovery doubtless led to all the subsequent applications of the one great fact—the production of electricity without friction, as in the electrical machine, and without chemical action, as in the voltaic battery. The first evidence we have of the practical application of magneto-electricity to the art of electro-deposition is in the patent of Mr. J. S. Woolrich, who in 1842 constructed powerful magneto-electric machines which were adopted by several large electroplating firms in this country. Since then many kinds of magneto-electric machines have been invented and applied with great success. Indeed the larger electroplating establishments have for many years employed such machines in place of the voltaic battery.

Dynamo-electricity.—The most important discovery of modern times, in connection with our subject and the electric light, is that of dynamo-electricity, and is due to the late Sir Charles Wheatstone and Dr. Siemens. These observers found that “induced currents of electricity, directed through the coils of the electro-magnets which produce them, increase their magnetic intensity, which in its turn strengthens the induced currents, and so on, accumulating by mutual action until a limit is reached.” Pursuing this subject with indomitable zeal, Dr. Siemens has been enabled to construct dynamo-electric machines for illuminating purposes which produce an electric light possessing great steadiness and brilliancy, and which now illumines the library of the British Museum, the Victoria Docks, ships of the Royal Navy, and many large manufactories. Of the numerous dynamo-electric machines which have lately been introduced, we may mention the Gramme which supplies the light on the Thames Embankment and elsewhere, and the Brush, now lighting South Kensington Museum, railway stations, and manufactories.

Although comparatively on its trial, the electric light has

during the past three years made great progress, and there is no doubt that in the course of a few years not only will our principal streets and public buildings be lighted by electricity, but also our larger manufactories and ships. That the electric light would never meet with general adoption if it were only obtainable by battery power there can be no doubt whatever, for the expense, inconvenience, and constant attention which a vast number of battery cells require, together with the comparative irregularity and uncertainty of the current obtained, has always barred the road to its successful adoption. The dynamo-electric machine has removed all these difficulties, and although we may look forward to many improvements in these machines, those we already possess are practically available for illumination.

The latest, and for our purpose the most important, improvement in the dynamo-electric machine for depositing metals is that recently invented by Mr. William Elmore of 91 Blackfriars Road, a diagram of which is given at fig. 21. In order that the student may fully understand and realize the advantages which the dynamo-electric machine possesses over the ordinary battery, we may state that the electric current is produced solely by motive power; there is no destruction of zinc, no consumption of acids, and but little attention required. A band connected with the revolving shaft of a steam-engine is attached to the small pulley of the machine, it is at once set in motion, and a current of great power is immediately at our service. About one-horse power is sufficient to produce the maximum amount of current in a medium-sized machine, and this is capable of depositing about 50 ounces of silver per hour.

The following brief description of this useful machine may not be uninteresting: "It consists of two standards AA, bolted upon the bed-plate B, to the inner sides of which are secured hollow 'sector-shaped' magnets in sets or pairs, facing each other. Between these is an iron disc having similar pairs bolted upon it. This disc or armature revolves by means of a shaft

passing through its centre. The magnets are wound with insulated, that is, covered copper wire. The magnets are connected in pairs alternately, that is, north and south pole. The shaft is fitted with a commutator to which the wires from the armature are attached, and this is in contact with a pair of copper brushes that lead respectively to a pair of large terminals.

The current generated in the stationary magnets passes by the terminals through a current regulator to the depositing bath. The current regulator is a simple but effective apparatus, and is entirely automatic. The object of this contrivance is to make it known at once if a reversal of current takes place—a most important advantage, inasmuch as the reversal of the proper course of the current would be very disastrous in electro-deposition, by causing the metal deposited to become again dissolved and deposited upon the opposite pole. Before a reversal of the current takes place in dynamo-machines a momentary stoppage precedes it; this interval, short though it be, is turned to account in the new regulator, which is so constructed that an alarm bell is brought into circuit which continues to ring until the operator adjusts the irregularity which would have caused a reversal of the current, and all goes on well again. This is a most valuable safeguard, and renders the dynamo-electric machine a perfectly safe instrument even in the hands of inexperienced persons.

Thermo-Electricity.—Electricity has also been produced by heating the lower half of two plates of metal of opposite character, as bismuth and copper, while the upper half is kept cool. This discovery was made by Seebeck of Berlin, and is termed thermo-electricity. Fig. 19 represents a pair of plates united by solder. B is a plate of bismuth and A one of antimony. The dotted lines indicate that the lower half of the pair of plates is to be heated, and the upper half cooled, while the current is taken off by the wires attached to each plate. The author once constructed a battery of 2000 pairs of such plates the soldering

of which occupied him about two months. Owing to the extreme fusibility of the bismuth when mingled with the tin solder, it was found impossible to get a workman to undertake the task.

II.

Application of Electricity to the Deposition of Metals—Electrotyping—Electroplating—Gilding—Nickel-plating, etc.

Electrotyping.—Now that we have seen how electricity can be produced at will, by chemical action, as in the voltaic battery, or by motive power, as in the dynamo-electric machine, we arrive at the second part of our subject, namely, the application of the current to the deposition of metals upon each other for various useful and ornamental purposes. The simplest process of electro-deposition is that which is called the "single-cell process," and it is this which constituted the first practical application of electricity to the arts; and was in fact the basis of the art of electrotyping as first published by Jordan in 1839, and subsequently claimed, but not justly, by others.

A small jar (fig. 15) is about three parts filled with a saturated solution of sulphate of copper. A porous cell, in which is placed a zinc bar, with binding screw attached, is to be filled with a strong solution of common salt or sal ammoniac to the same height as the copper solution.

We next proceed to prepare a mould upon which to deposit copper in this simple apparatus. A piece of gutta-percha is rendered soft by immersion in hot water for a few minutes; it is then to be removed and rolled in the palms of the hands until it assumes the form of a ball. If the softened gutta-percha be now carefully, but firmly pressed upon the face of a coin or medal,

and allowed to remain until quite cold, we obtain a perfect impression of the original. This is termed the mould, but since gutta-percha is non-metallic, and therefore not a conductor of electricity, it will be necessary to give it a conducting surface artificially. Plumbago, or blacklead, is employed for this purpose, and is to be well brushed over the face of the mould until it assumes the characteristic metallic lustre of this substance. A short length of copper wire is next to have one end heated and pressed into the edge of the mould, and this must then be set aside to cool, after which plumbago is to be brushed over the junction. When quite cold the opposite end of the wire is to be bent at a right angle and inserted in the binding screw. The mould is now ready to receive the deposit or coating of copper. The zinc bar is to be carefully placed in the porous cell, and the mould gently lowered into the copper solution, where it must be allowed to remain for at least twelve hours without being disturbed. A few moments after immersion a bright deposit of copper will appear at the end of the wire, and this will gradually radiate from this point until the entire surface of the mould is covered with metallic copper. By continuing the operation for about twenty-four hours we shall obtain a deposit of sufficient thickness to enable us to separate the mould from the deposited metal. The best way to accomplish this is to place the mould in hot, not boiling, water for a few moments, when the gutta-percha, being softened, may be readily removed from the electrotype, as it is called, and which will be found to be a perfect copy of the original object, exquisitely sharp in all its minutest details. At fig. 16 is shown an arrangement for depositing upon several moulds in the same bath.

For large electrotyping operations it is usual to employ a separate battery and bath, as in fig. 23. The moulds are connected with the negative pole of the battery, and copper plates, attached to the positive pole, are immersed in the copper solution. By this arrangement the copper plates become dissolved in the solution.

while electro-deposition is going on, and thereby the solution is kept in a uniform condition.

Faraday employed the term *electrode* to each of the conducting wires of the battery, as *positive electrode*, or *anode*, for the conductor which conveys the current *into* the solution bath, and *negative electrode*, or *cathode*, for the conductor through which the current makes its exit *from* the bath. It will be understood, then, that the dissolving plate, whether of copper, silver, gold, or other metal, is termed the *anode*, and the article to be coated is the *cathode*.

While by employing a separate battery we are enabled to keep the solution in a uniform condition, as we have said, in the "single-cell" arrangement it is obvious that the reverse will follow, unless we adopt some means of supplying the solution with metal as it becomes deprived of it by deposition of copper upon the mould. This is effected by adding fresh crystals of sulphate of copper to the solution from time to time.

If we bear in mind that metallic solutions, when decomposed by electricity, give up their metal to the article coated, and that the anode or dissolving plate re-supplies the solution with an equivalent of metal so deposited, we shall see at once that, all things being equal, the solution—when a separate battery is used—should maintain perfect uniformity. Spontaneous evaporation, however, will of course somewhat alter its condition, by removing a portion of its water, but the equilibrium is readily restored by adding water from time to time as required.

Moulds for electrotyping purposes may be made of wax, fusible metal (an alloy of bismuth, tin, and lead), and many other substances, but for the purposes of preliminary study gutta-percha or white wax will answer well. Plaster medallions and busts, rare coins, and even insects, ferns, and fishes may be reproduced in pure copper by the electrotype process, and the appearance of real bronze may be imparted to the deposited metal by a mixture of jewellers' rouge, plumbago, and sulphide of

ammonium, applied in a moist state with a soft brush, the article being finally polished with a dry brush.

Electroplating, or more properly electro-silvering, consists in employing a solution of double cyanide of silver and potassium, and a silver anode for the dissolving plate. A silvering bath is represented at fig. 18. The articles to be plated are previously prepared by brushing them well with powdered pumice moistened with water. They are next well rinsed and then suspended by copper wires from brass rods placed across the depositing tank. These rods are in direct communication with the positive element (zinc) of the battery, while the silver anodes are connected with the negative (copper) element. It is usual to leave the articles in the silver bath from eight to twenty-four hours when ordinary battery power is used, but when the dynamo-electric machine is employed an equal amount of deposit will be obtained in about one-third of the time. When the necessary thickness of coating is obtained the work is removed from the bath and rinsed in clean water. The silver deposit has generally a dull white frosted appearance, which is easily brightened by friction. The articles are then "scratch-brushed," as it is called, by which process they become considerably brightened. The scratch-brush consists of a series of fine brass-wire brushes fastened to a disc of wood, or "chuck," screwed to the head of a lathe, which is caused to revolve in the usual way. After the work has been thus treated it is either polished or burnished, by which means it acquires the beautiful lustre so much admired in electroplated goods. The polishing process is effected by means of rotten-stone and oil, applied with leather "bobs" and "buffs," and finally the work is finished by applying jewellers' rouge—pure peroxide of iron.

The burnishing process is accomplished by passing over the surface of the plated articles certain tools made of steel, agate, or bloodstone, whose surfaces have been prepared by polishing in the highest degree of which they are susceptible. These tools

are made of various designs to suit the varied forms of the articles to be burnished. The art of burnishing is practised chiefly by women and girls, who frequently become famous for the beauty of the work they accomplish.

Electroplating is carried on very extensively in London, Birmingham and Sheffield, but most extensively in the latter towns, where it forms one of the most important industries, and involves the employment of a vast number of persons. It is purely a scientific or chemical art, and although it is in itself exceedingly simple, considerable practical knowledge is required to practise it successfully, owing partly to the varied character of the articles which are required to be plated. There is scarcely a part of the civilized globe in which plating or gilding by electricity are not practised in some degree or other.

Electro-gilding is an equally important branch of the art, and though similar in principle to electroplating, is very different in its practical aspect. Gilding is generally conducted with warm or hot solutions of cyanide of gold and potassium, and since the coating of this precious metal is not required to be so thick as in silver-plating, a few minutes', and very often a few seconds', immersion in the bath is sufficient. Many articles of cheap jewellery are momentarily dipped in the bath, rinsed, and scratch-brushed; again rinsed, then placed in hot boxwood sawdust, and after a final shaking in the hand or in a hair sieve to remove the sawdust, are ready for sale. This kind of gilding forms a very extensive, if not exalted, industry, and gives employment to a great number of hands, large and small.

When it is required to gild the inside of a vessel, as a cream-ewer or mug, for instance (fig. 17), the vessel is filled with gold solution, the negative electrode attached to the handle of the vessel, and a gold plate, connected with the positive electrode, is suspended in the solution, but kept free from contact with the vessel itself. In a few minutes, generally from five to ten, the required coating is obtained, when the anode is removed and the solution

poured out. After rinsing in warm water the inside of the vessel is scratch-brushed with a brush of suitable form and finally burnished.

Nickel-plating differs somewhat from silver-plating, and since it is fast becoming of great importance in this and other countries, a few observations concerning it may not be uninteresting. Nickel, as is well known, is an exceedingly hard metal, and consequently a surface of other metal coated with it is very durable. Being nearly as white as silver, and not liable to become discoloured in an impure atmosphere, nickel presents great advantages as a coating for steel, copper, or brass articles. In depositing nickel it is usual at the present time to employ dynamo-electricity, though the Bunsen battery (fig. 9) or the twin carbon battery (fig. 13) may be used for small operations. Nickel-plating is, however, generally carried on upon an extensive scale. The depositing tanks usually hold from 200 to 500 gallons of solution, and the anodes are cast nickel plates, at least half an inch thick, about 6 or 7 inches wide, and from 18 to 30 inches long. From sixteen to thirty of such plates are employed in each bath. Owing to the solution of nickel, which is generally composed of the double sulphates of nickel and ammonium, being an indifferent conductor of electricity, a powerful current is required to enable the operation to be conducted with energy. Nickel-plating is a very interesting branch of the art of electro-deposition, but it requires skilful manipulation to pursue it successfully. The articles to be coated with this metal must be thoroughly clean and free from oxidation. The work is usually prepared for plating by being first polished with fine sand and then finished with powdered unslaked lime. It is next placed in a hot solution of caustic potash to remove grease, and afterwards well rinsed in clean water. Then (if the article is of brass or copper) it is dipped in a solution of cyanide of potassium to remove any oxide that may appear upon the surface. After again rinsing, the work is scoured with finely-powdered

pumice, and after a final rinsing it is ready for the nickel-bath. In this the article is allowed to remain undisturbed until the required coating is obtained, when it is rinsed in boiling water and sent into the polishing-room to be finished. Sheffield lime, in a fine powder, is used for this purpose, and it is applied at a lathe set in motion by steam-power, by means of "buffs" and "dollies," the latter being circular discs or "mops" formed of many layers of calico. By these means the finisher is enabled to impart to the nickel surface a most brilliant polish, equal at least, if not surpassing, the finest polished steel.

Other metals and alloys of metals are deposited by electricity. An alloy of copper and zinc, forming brass, is extensively employed for many purposes. An alloy of copper, nickel, and zinc, representing the so-called German silver, is deposited upon iron and other metals. Iron is deposited upon copper electrotypes, engraved plates, and other surfaces to give additional hardness to the softer metal, and thus preserve the more delicate touches of the graver or etching-needle. With the exception of tin, however, the metals and alloys we have mentioned are those chiefly dealt with by the practical electro-metallurgist.

Resistance Coils.—When a powerful current of electricity is required for the purposes of electro-deposition, as in the case where the dynamo-electric machine is employed, it is usual to apply a "resistance coil," as it is termed (fig. 20), the object of which is to check or control the current after it leaves the machine or battery, and before it enters the depositing tank. To explain the action of this instrument it will be necessary to state that when a powerful current of electricity is put on short circuit by a thin copper or other conducting wire, the resistance to the current is so great that the wire becomes red hot, even to fusion. The wire employed for conducting the current from a dynamo-electric machine is generally at least a quarter of an inch in thickness. Now if the circuit between the two poles is completed by a thin copper or iron wire, it soon becomes intensely hot, and finally

melts at its centre and breaks, by which the two poles become separated again. It is this fact which led to the employment of electricity for the purposes of illumination. Figure 22 illustrates the electric arc formed between two carbon points, which nearly, but not quite, touch each other. Now when the electric circuit is completed by allowing the carbons to come in contact, an incandescent light is at first obtained, and as the carbons become consumed, a bright luminous space occurs between them, which is called the electric arc—the temperature at which point is very high, indeed far higher than any heat we have the power to produce in any other way artificially. The thin wire of the resistance coil, therefore, has the power to keep back the current, so to speak, and thus enable us to control its force while we are filling our plating tanks with work. The coil is provided with a switch, by means of which we can regulate the force of the current at will. By moving the switch to the peg on the right hand, the current is altogether cut off from the plating tank. If we place it on the next peg in the series, a certain amount of current passes, and so on. As we bring the switch nearer to the left, the resistance is diminished proportionately, and consequently a greater amount of electricity is suffered to enter the plating-bath.

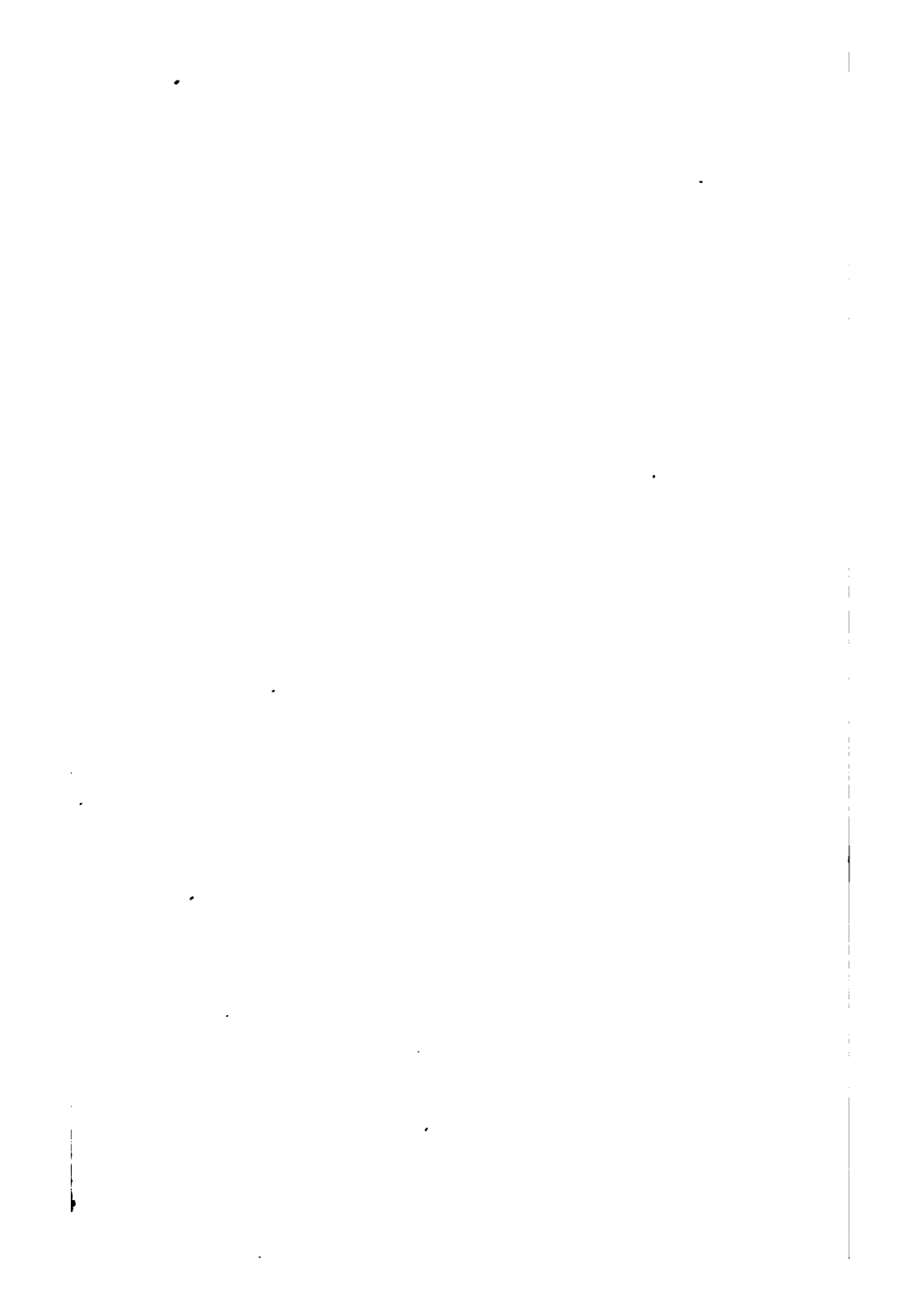
Binding Screws are used for making connections between the battery plates, or cylinders, and the plating vat. Various forms of these are given in the Plate, but there are many other designs employed to which it is not necessary to call attention.

Electricity is now extensively employed in extracting valuable metals from their ores; and when dynamo-electricity becomes farther developed, it will doubtless supersede the furnace to a great extent in the process of refining metals.

As a motive power, electricity will probably some day replace steam; and it is equally probable that many of our large chemical operations will be conducted by aid of the electric current. Its grand application in our telegraph system, and in

transmitting sound, as in the telephone, together with its invaluable service in depositing metals from their solutions, will have prepared our minds for any future applications of electricity, however startling and marvellous they may be.

In conclusion, it is hoped that the student may have gleaned sufficient knowledge of Voltaic Electricity, as applied to the deposition of metals, to enable him, should he desire it, to study the art in a more practical way. As a means of recreation for long winter evenings, the simple, yet beautiful art of electrotyping will be found most enjoyable, while as an intellectual pursuit it has much to recommend it.



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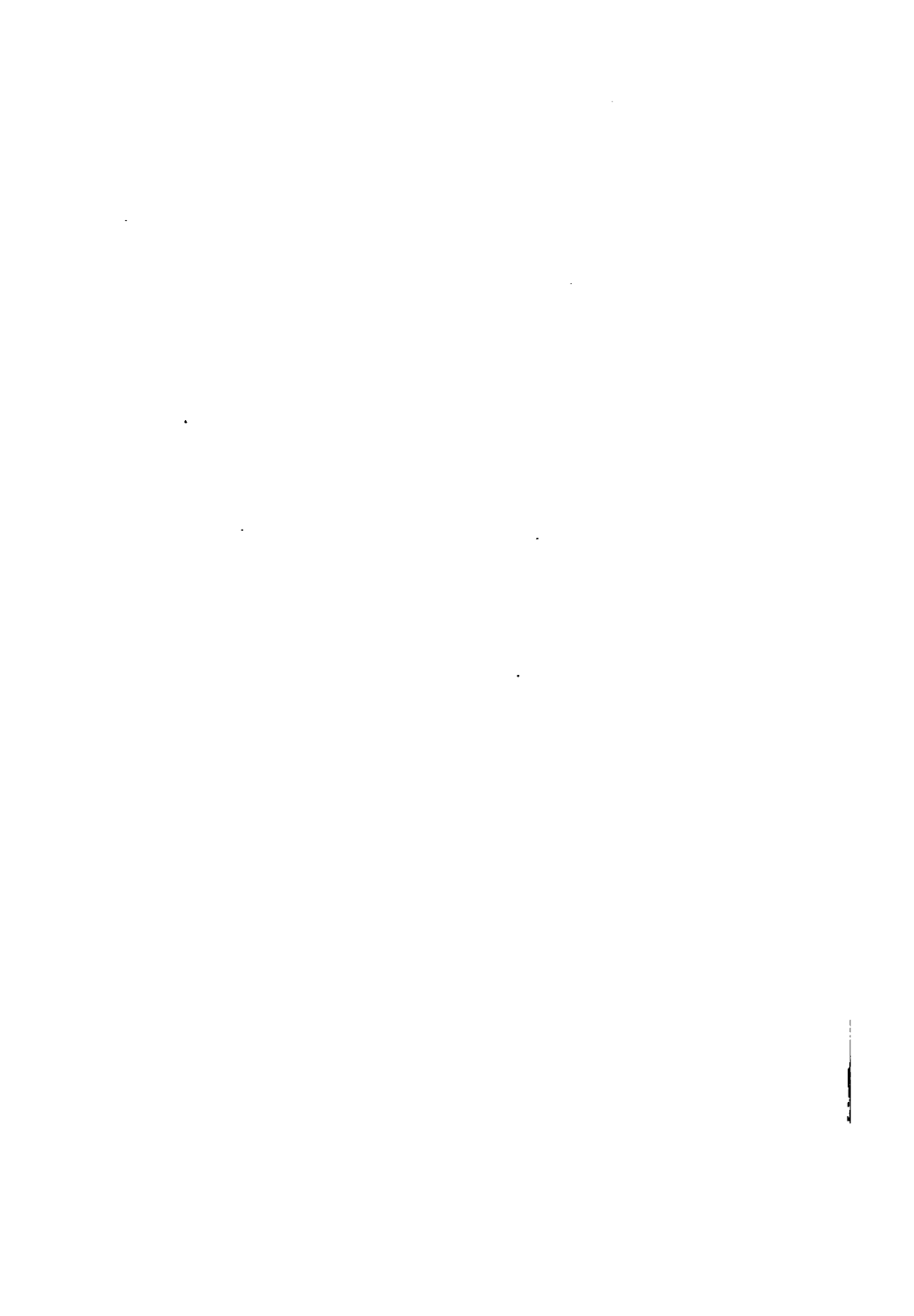
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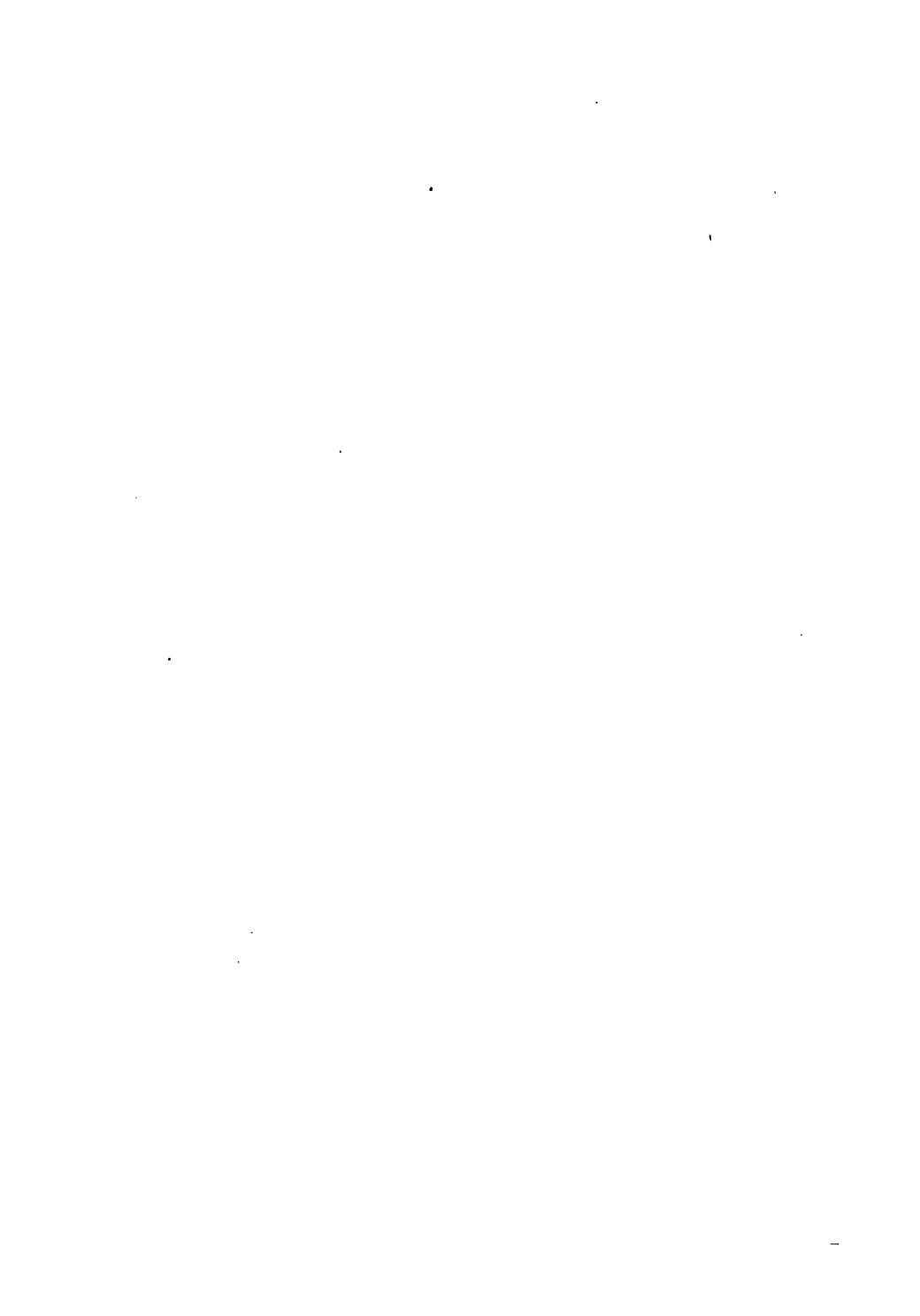
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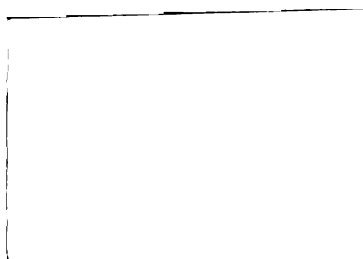












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